Structural Mode Identification of Galileo Spacecraft from Flight Data

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Abstract

This paper describes a scheme to identify the flexible mode characteristics (frequency, damping, and modal coefficient) of the stator using frequency domain analysis approach, and how the simulated results arc compared with results derived by using actual flight data. The identified mode characteristics may be used for updating the scan platform controller parameters in flight. A description of the in-flight identification approach of the Galileo Spacecraft flexible modes is given in Reference [1].

Flight Data Acquisition

The purpose of acquiring measured gyro flight data and using them for in-flight identification of the structural resonance frequencies is to locate the "destabilizing frequencies" and "mode shape" such that proper notch filter parameters in the onboard software can bc determined and subsequently reloaded by sending uplink commands to the spacecraft.

Due to the problem of being unable to deploy the Galileo High Gain Antenna, the ability to perform inflight system ID by sending gyro output of high data rate (1 200 bits/see) has been severely curtailed. only one rare opportunity was provided when the spacecraft was encountering the Earth the second time, high rate gyro data was able to be stored and transmitted to Earth using the low gain antenna. Therefore, only one set of telemetry data from flight was obtained and processed to identify the flexible mode characteristics of the stator. The identification command sequence and telemetry data was executed ant] sent back on 1 /20/93.

The identification procedure starts with exciting the SBA with five different pulses of 7, 8, 9, 10 and 11 Real Time interrupts (RTI), where one RTI is 66 2/3 mscc. Then the gyro telemetry data are obtained with SBA friction compensated. A special mode for telemetry, known as the " flood mode", provides up to six measurements of telemetry variables at a rate of 66 2/3 msec. Each memory readout from the bulk memory contains a maximum of 38.67 sec of sampling at 15 samples per scc, or a total of 580 samples pcr telemetry variable.

Gyro data is the only sensor data that can provide adequate resolution in sensing the platform's rate and position. The rate information of the platform can be measured directly from the position increments of the rate integrated gyro outputs. This is because the time duration in between samples can be assumed constant during the period that the gyro sample arc collected, wc can simply usc the position increments directly as a rate information.

Identification Strategy

The stator structure to which the platform is attached is quite flexible. It has several very lightly damped natural frequencies below 15 Hz. Furthermore, the clock actuator is separated from the gyro by the flexible stator. Evaluation of the structural data indicates that the stator structure modes that arc of greater impact to the the platform controller exist in the range of 2.5 - 15 Hz. These frequencies are near the controller bandwidth of around 0.5 Hz.

The Galileo scan pointing algorithms in clock axis consists of a scan commander and a proportional-integral-derivative controller with a notch filter. To stabilize the pointing system, a notch filter is added to the controller to greatly attenuate the control system gain at the notch frequency. 'l'he objective is to use the filter to reduce the resonance peaks in magnitude to levels having reasonable. stability margins. The design used two cascaded notches, or a double notch filter. The double-notch approach provides twice the amount of attenuation as a a single notch,

If the structural frequency has been identified to have a large resonance peak, the notch frequency will be set exactly at that frequency to achieve maximum attenuation. On the other hand, depending on how the structural modal frequencies are being identified, the adjustment to the parameters in the notch filter can bc quite different. For example, if the structure has a number of modal frequencies with large resonance peaks, then rather than picking one of these frequencies to be notched, wc may use the notch filter more as a low pass or rolloff filter. in this way, the filter would attenuate frequencies higher than the notch frequency, and pass the lower frequencies with little or no attenuation. The problem of using a wide notch filter is that while it may do a good job in resonance attenuation, it also could reduce the controller bandwidth and degrade the platform's pointing performance.

The modal frequencies are first determined by analyzing the PSD of the gyro telemetry data measuring the stator response. The model PSD is also generated using the same input torque (same magnitude and pulse width). Both modal coefficients and damping factor of each mode are estimated such that the model can reproduce the same spectrum as the one produced from flight data, both in frequency and amplitude, to some satisfactory accuracy.

Results of Inflight data processing and Identification

(All the required telemetry had been received and is currently being processed. The identification results will bc discussed in detail in the final version of the paper)

Conclusion

identification of flexible mode characteristics in frequency, damping, and modal coefficients, of the Galileo stator structure using in-flight telemetry data is performed. The approach is based on a scheme using a sequence of torque pulses of variable width produced by the spin bearing assembly actuator, and capturing the raw gyro data. A frequency domain analysis approach is taken that involves generating a power spectral density of the structural response data. "l'he result of the identification may be used to adjust notch filter parameters in the onboard software which controls the scan platform.

Reference:

[1] "In-flight identification of the Galileo Spacecraft Flexible Mode Characteristics" E. C. Wong. Journal of Guidance, Control, and Dynamics, Vol 9, Number 1, Jan 1986

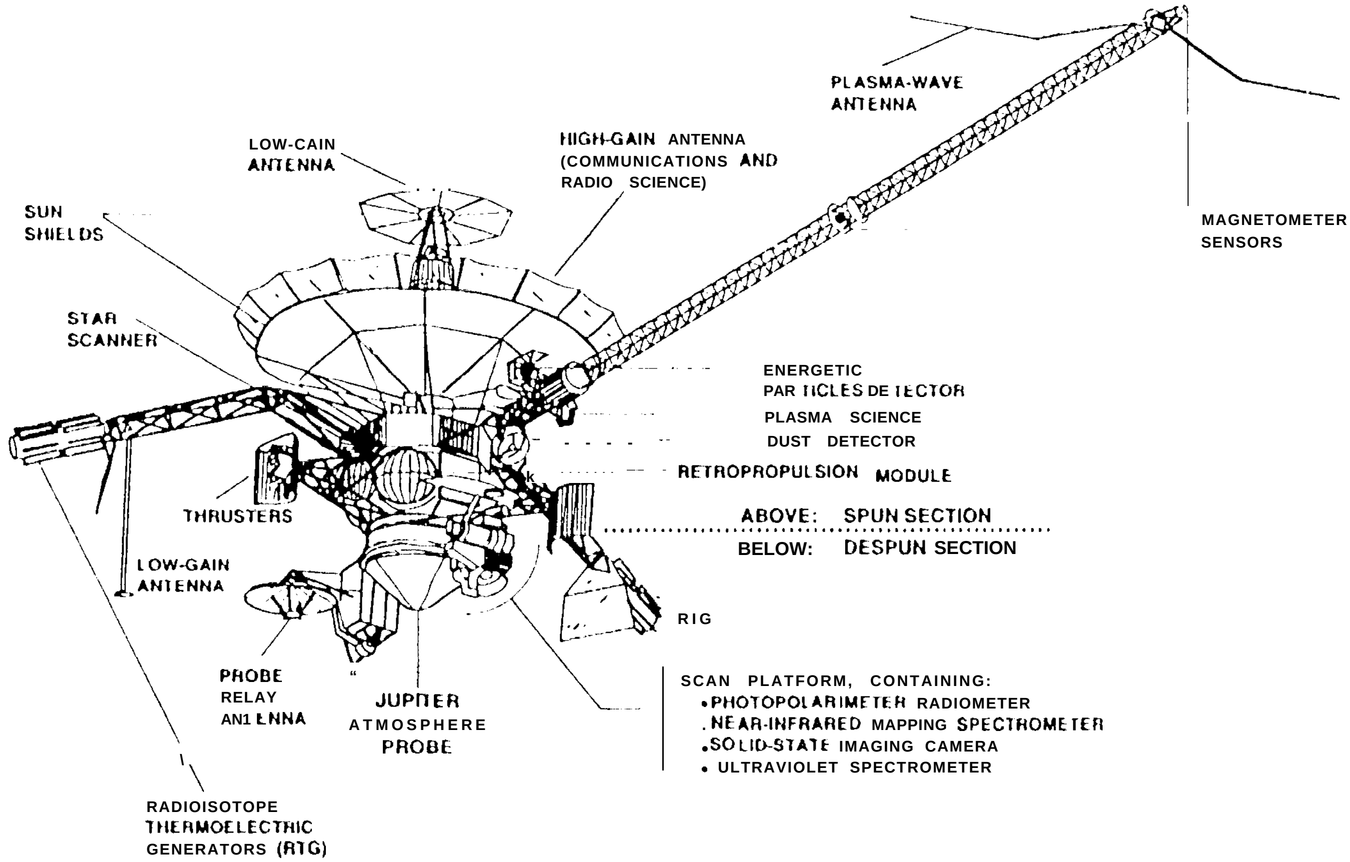

Fig 1. Galileo spacecraft